CO_2 Laser Frequency Multiplication

Report for January 1992

Contract No. 00014-91-C-2279

The month has been spent in a series of harmonic generation experiments at increasing peak intensity and fluence. Second harmonic beam quality has been measured.

Using the oscillator alone, with grating selection of the 9.55 μm line, the pulse train consisted of a "spike" containing about 10 pulses followed by a "tail" containing about 40 pulses. Both the "spike" and the "tail" contained approximately equal energy, the combined total going as high as 180 mJ. The crystal was located near to the plane exit mirror of the oscillator, where the near-parallel beam had a Gaussian (amplitude) spot parameter of 0.46 cm. The on-axis fluence was 0.5 J cm^{-2} and the peak intensity in the 2 nsec optical pulses was approximately 20 MW cm^{-2}. The pulses were separated by 40 nsec. Energy conversion efficiency of up to 31% was recorded, with 56 mJ of second harmonic (outside the crystal) for 181 mJ of incident 9.55 μm radiation. The second harmonic energy depended on the 1.5 power of the fundamental in the fundamental energy range 50 mJ to 180 mJ. Time-dependent analysis showed that the conversion efficiency was close to 50% in the "spike" but generally less than 10% in the "tail" as expected from their intensity ratio (in the range 4:1 to 8:1).

The spot size of the fundamental and second harmonic beams was measured at distances of 0.18, 5.6 and 18.7 meters from the crystal (the fundamental without the crystal in place). All the data correspond precisely to the propagation of Gaussian beams at the theoretical diffraction limit. The crystal, which had previously given evidence of optical perfection via its narrow angle range of phase matching, was generating a theoretically perfect second harmonic wavefront.

A second high power doubling experiment involved amplification of the "spike" alone. By restricting the oscillator mode selection aperture the "tail" could be reduced to almost zero. The "spike" was then amplified to an energy of 178 mJ by passage through two

amplification stages (40 cm each). The beam was converged very slightly (9.75m mirror) before entry to the amplifier and it entered the crystal with a calculated spot (amplitude) parameter of 0.36 cm. The fluence was 0.9 J cm^{-2} and the peak on-axis intensity was approximately 50 MW cm^{-2}. In this experiment, with short pulse trains of about 10 pulses, the energy efficiency of second harmonic generation reached 50% (88 mJ at 4.775 μm from 177 mJ at 9.55 μm).

A third experiment involved longer pulse trains from an oscillator injected at 9.55 μm to obtain line-locking as described in previous monthly reports. The amplitude of the "tail" was thereby increased relative to the spike (to the range 1:4), then after passage through an amplifier, the tail was increased to the same magnitude as the spike. A 2 μsec pulse train consisting of about 50 pulses, with an energy of 349 mJ, generated a second harmonic energy of 68 mJ. The fluence was 0.95 J cm^{-2} and the peak intensity was approximately 10 MW cm^{-2}. The conversion efficiency was 19.5%.

An unexpected problem has arisen in the purchase of the frequency tripling crystal. Cleveland Crystals, the only supplier, stated suddenly that the material (either Type I or Type II) was not available for this mixing process, after quotations and documentation had been received and the TDS Purchasing Department was on the point of placing the order. The problem is that most 1991 boules have had multiple crystalline character and the supplies of good material have literally run out. Our work statement proposed tripling and quadrupling on a best effort basis, "as time and funding permit". In the circumstances, we wish to devote more time to other measurements, not mentioned in the work statement, such as thermal conductivity, and variation of refractive index with temperature. We have designed a simple experiment to measure the thermal conductivity, which we hope to attempt in the coming month. Also, there is more harmonic generation to be done, involving higher fluences and, if possible, shorter mode-locked pulse durations.

To date, there is no external sign of damage to the crystal after several tens of pulses in each of the above conditions.

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